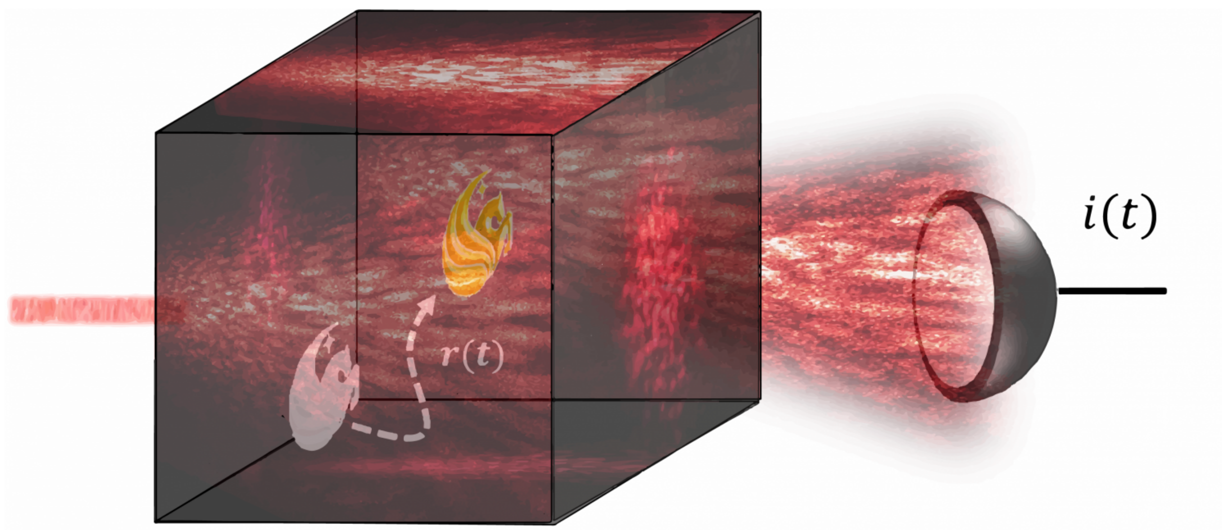
By listening to optical 'noise,' researchers discover new way to track hidden objects

April 20 2017



The system tracks a target enclosed in a 'scattering box' that impedes direct imaging. As the object moves, it imposes fluctuations on the light coming out of the box. The light is then collected by an integrating detector, which uses an algorithm to distinguish natural noise from the fluctuations caused by the object. Credit: Aristide Dogariu, University of Central Florida

Researchers have developed a new solution to tracking objects hidden behind scattering media by analyzing the fluctuations in optical "noise" created by their movement. In The Optical Society's journal for high impact research, *Optica*, researchers from the University of Central Florida (CREOL) demonstrate their technique by tracking the location of an object as it is moved within an enclosed box.

The approach could help advance real-time remote sensing for military and other applications. For example, it could be used to track vehicles or aircraft traveling through fog. It could also be useful for areas of biomedical research that involve fast-moving particles that cannot be observed directly, according to the researchers.

There are many technologies capable of detecting, describing and tracking objects that are far away or that cannot be observed visually. However, most existing technologies, such as Light Detection and Ranging (LIDAR), require a line of sight between the object and the sensor, which means they do not work well when the object is obscured by clouds, fog or other conditions that scatter light.

"We are promoting a paradigm shift," said Aristide Dogariu from the University of Central Florida and leader of the research team. "Instead of illuminating the object with a coherent beam of light, we're illuminating it with random light. Looking at how the fluctuations of the light are modified by the interaction with the object allows us to retrieve information about the object."

Insights without a line of sight

Existing tracking technologies use one of two approaches. Laser-based methods such as LIDAR point a beam of light at the object and then move the beam around to deduce information such as the object's size, shape and trajectory. Imaging-based methods, on the other hand, take a series of images of the object and then perform computations to track its movement over time.

"These are very good strategies that have been in place for decades, and under ideal conditions their performance cannot be surpassed," said

Dogariu. "But as soon as something in the line of sight scatters and randomizes the light, you run into problems."

Dogariu's team has spent more than a decade learning how to infer information from the fluctuations in light; they previously applied these concepts to developing new tools for sensing the properties of materials and for super-resolution microscopy. In their latest research, they sought to track moving objects in conditions where it is not possible to see the object and not possible to control or pinpoint the directionality of the light shining on it.

"An object that is hidden behind some scattering diffuser is not illuminated by a spatially coherent beam," said Dogariu. "The movement of the object, the size of the object and the properties of the object affect the statistical properties of the noise-like optical field, and this effect is what we measure."

Because light behaves in a predictable way, Dogariu's team was able to develop statistical methods to separate natural noise from fluctuations that are created by the movement of the target object.

Testing the method

To test the approach, the researchers enclosed a small object within a plastic box that is designed to scatter light. Shining a beam of coherent light onto one of the scattering walls creates a secondary light source inside the box. The target object scatters this light and then the light waves are further randomized when light passes back through the scattering walls. The light is then collected outside the box by an integrating detector, which uses an algorithm to distinguish natural noise from the fluctuations caused by the object.

"If the target that is surrounded by this enclosure starts to move, then the fluctuations that it imposes on the light coming out of the box can be detected from any direction very efficiently," said Dogariu. Although it can detect the hidden object from any location outside the enclosure, the system cannot identify a non-moving object.

Some other technologies have recently been developed that allow tracking of obscured objects by repeatedly scanning or imaging them over time. However, those approaches require complex optical instruments and large-scale data processing, which can make them impractical for following fast-moving objects.

In their experiments, Dogariu's team was able to accurately track the movement of the object within the scattering enclosure in real time using a simpler and more versatile setup. "The advantage of recovering information based on fluctuations is that it is more robust against external perturbations," said Dogariu. "It is robust against disturbances between the light source and the object and between the object and the receiver."

New opportunities

Because the system extracts information about movement in each direction independently, the approach efficiently senses position for all degrees of freedom (left-right, up-down and diagonal). In addition, because the method follows the motion of the target's center of mass, the tracking accuracy is not affected when the object tilts or rotates.

The method's main drawback is the limited level of detail it can provide about the target object. While it can detect the speed and direction at which the object moves and may be able to reveal the object's size, it cannot reveal its color, material, or necessarily its shape.

"You cannot recover detailed information with this method, but if you simplify the question to what you really need to know, you can solve certain task-oriented problems," said Dogariu.

As a next step, the team is working to refine the approach to handle more complex environments, larger scenes and scenes with lower levels of incoming light. Their hope is that these improvements will bring the system closer to real-world applications in biomedicine, remote sensing and other areas.

Though the research involved light waves, similar noise-based approaches could be implemented in other domains, such as acoustics or microwaves, Dogariu said.

More information: Milad I. Akhlaghi et al, Tracking hidden objects using stochastic probing, *Optica* (2017). DOI: 10.1364/optica.4.000447

Provided by Optical Society of America